Calculation of the Cross-sectional Areas of Circuit Live Conductors and Cables Considering Overcurrent protection of the cables

Overcurrent can be subdivided into overload current, and short circuit current.

- Overload
  This is caused when too many appliances are connected on the circuit or applying excessive mechanical load on a machine.
- Fault
  This is caused when failure of insulation occurs.

1.Overload protection

An overload may result in currents of two or three times the rated current flowing in the circuit.

A protective device must be used to break overload current before any thermal damage is done to cable insulation. The selected protective device should have a current rating which is not less than the full load current of the circuit I_b but which does not exceed the cable current rating I_z. This can be explained as follows:

- The nominal rating of the protective device:
  Greater than the design current of the circuit and less than the operational current of the cable conductor.

$$I_b < I_n < I_z$$

- The operating current must not exceed : $1.45 \times I_t$

The cable is then fully protected against both overload and short-circuit faults.

Note : The above overload protection may not be applied for the cases when the load is such that is not likely to be overloaded such as a fixed lighting systems.

2. Fault or Overcurrent protection

Fault current is usually caused by short circuit faults due to the failure of cable insulation or between two live conductors of the system or any other reasons.

The initial surge current may exceeds thousand of amperes (kA) and need to be disconnected very fast. The short circuit level in the circuit will decide the short circuit rating of the protective device.

When selecting a protective device we must give consideration to the following factors:

The prospective fault current.
The circuit load characteristics.
The current carrying capacity of the cable.
The disconnection time requirements for the circuit.

Protective Devices

Devices which provide overcurrent protection are:

- Fuses

1- *Semi-enclosed fuses:* These were previously called rewirable fuses and are used mainly on domestic installations having a maximum fault capacity of about 4 kA. (*BS 3036*

2- *Cartridge fuses:* These are used for a.c. circuits on industrial and domestic installations having a fault capacity of about 16 kA to 30 kA.(*BS 1361& BS 1362*

3- HBC (or HRC) fuses: High Breaking Capacity or High rupturing Capacity are used for industrial applications having a maximum fault capacity of 80 kA. (*BS 88-6 or* BS 88 'gG')

These fuses are shown in Fig.1 and 2.

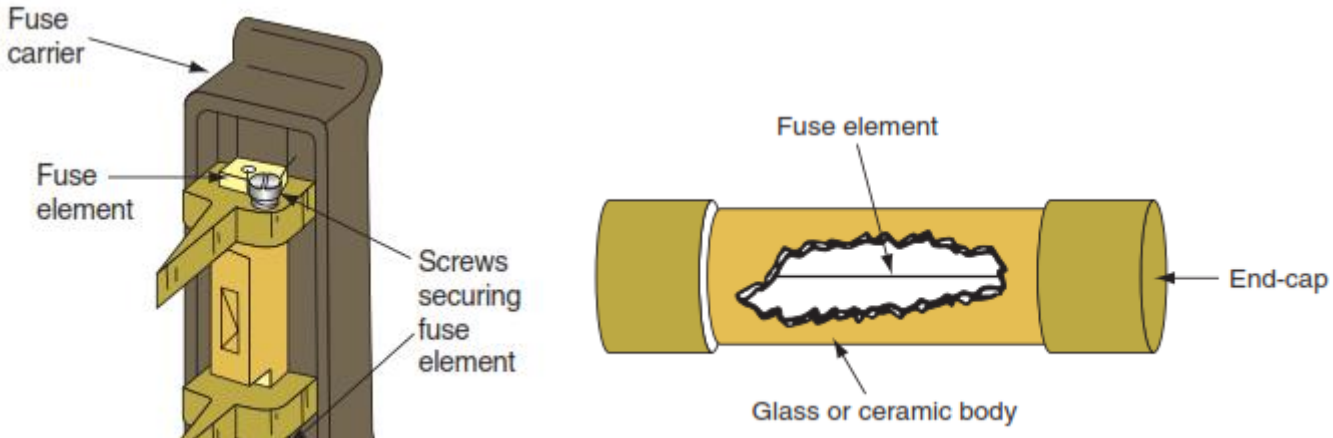


Fig. 1

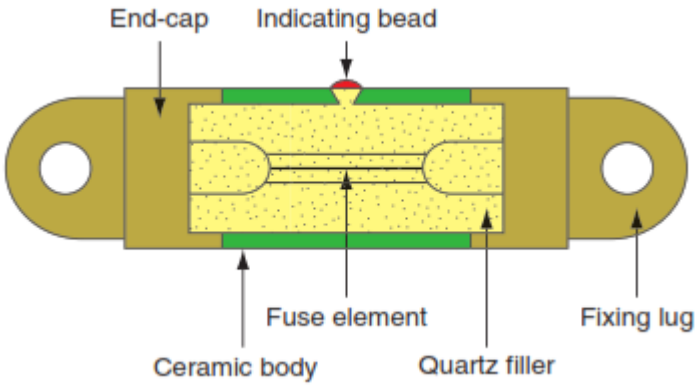


Fig. 2 HBC fuse.

- Circuit Breakers

Miniature circuit breakers (MCBs): These are MCBs which may be used as an alternative to fuses for some installations. The Standards includes ratings up to 100 A and maximum fault capacities of 9kA. They are graded according to their instantaneous tripping currents –that is, the current at which they will trip within 100 ms.
Types of MCBs :

- *MCB Type B: This type* will trip instantly between three and five times its rated current and is also suitable for domestic and commercial installations.(*BS EN 60898)*

(I_m = above $3I_n$ up to and including $5I_n$)

- *MCB Type C: This type* will trip instantly between five and ten times its rated current. It is more suitable for highly inductive commercial and industrial loads.(*BS EN 60898)*

(I_m = above $5I_n$ up to and including $10I_n$)

- *MCB Type D: This type* will trip instantly between 10 and 20 times its rated current. It is suitable for welding and X-ray machines where large inrush currents may occur.(*BS EN 60898)*

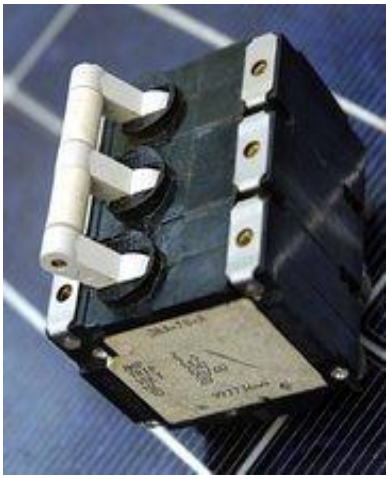
(I_m = above 10 I_n up to and including 20 I_n)

Where I_n = Normal (rated) current
I_m = Magnetic releases operating current range of the MCB.

MCB Construction

1. Actuator lever - used to manually trip and reset the circuit breaker. Also indicates the status of the circuit breaker (On or Off/tripped). Most breakers are designed so they can still trip even if the lever is held or locked in the on position. This is sometimes referred to as "free trip" or "positive trip" operation.
2. Actuator mechanism - forces the contacts together or apart.
3. Contacts - Allow current to flow when touching and break the flow of current when moved apart.
4. Terminals
5. Bimetallic strip
6. Calibration screw - allows the manufacturer to precisely adjust the trip current of the device after assembly.
7. Solenoid
8. Arc divider / extinguisher

Single- pole MCBs



Three – pole MCB.

Doble – pole MCB.

The commonly-available preferred values for the rated current are 6 A, 10 A, 13 A, 16 A, 20 A, 25 A, 32 A, 40 A, 50 A, 63 A, 80 A and 100 A

Fig.3 Miniature circuit breakers MCBs.

An MCB of the type shown in Fig.3 incorporates a thermal and magnetic tripping device. The load current flows through the thermal and the electromagnetic mechanisms. In normal operation the current is insufficient to operate either device, but when an overload occurs, the bimetal strip heats up, bends and trips the mechanism. The time taken for this action to occur provides an MCB with the ability to discriminate between an overload which persists for a very short time, for example the starting current of a motor, and an overload due to a fault.

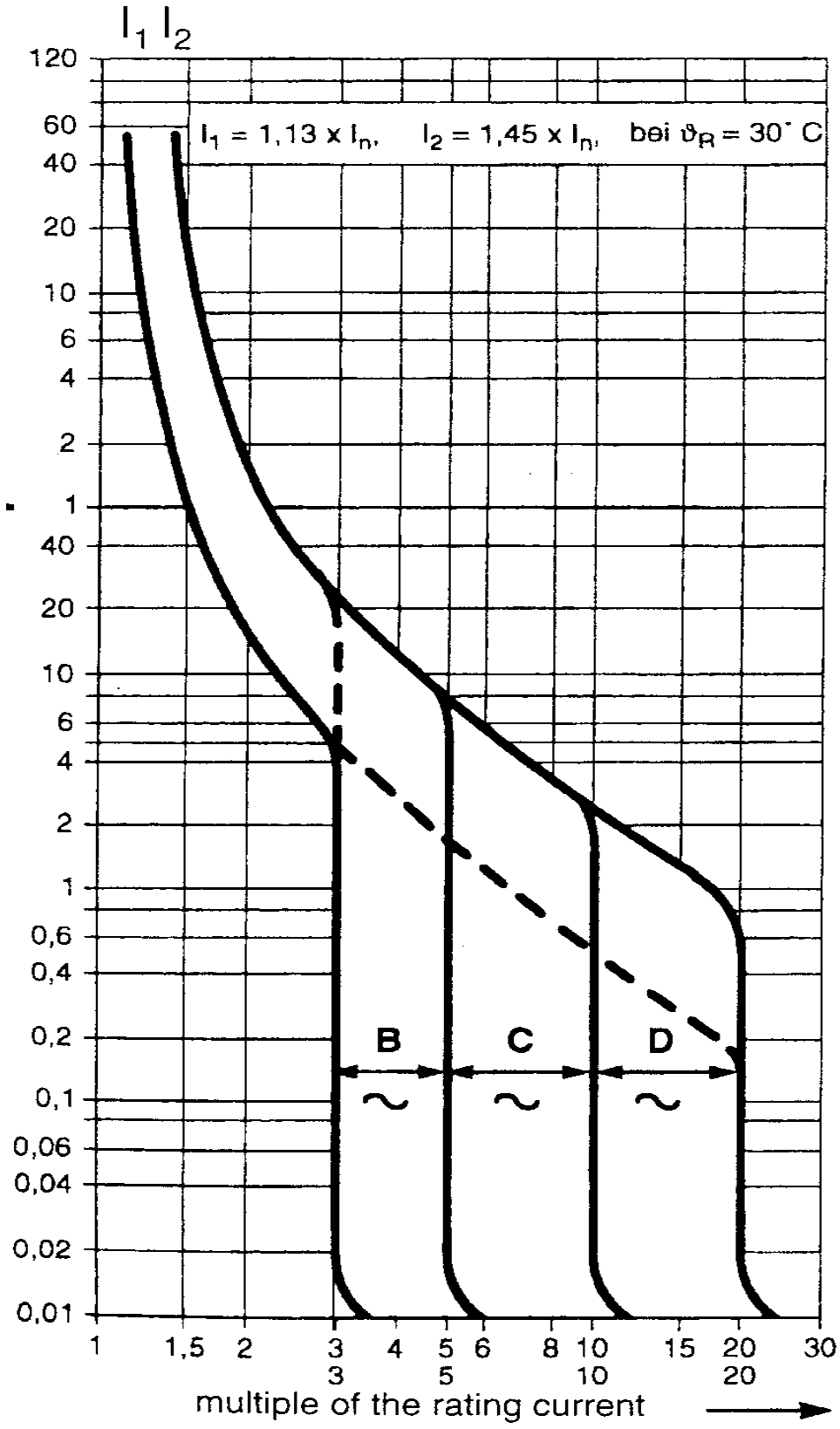


Fig. 4 MCB characteristics.

Example 1
A d.c. circuit has a design current of 28 A. It is to be wired in a two-core EPR cable having 85ºC rubber insulation and copper conductors. It is to be installed in trucking with five other similar circuits.
If t_a= 40ºC and the circuit is to be protected by a 45 A HBC fuse to BS 1361 against short circuit faults only, what is the minimum conductor cross-sectional area that can be used?

From Table (3-13), C_g =057 (approximated, since there being a total of 6 circuits).

From Table (3-18), C_a = 0.91
Also C_i = 1 , for HBC fuse : C_d=1,

Thus:
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$$I_t = 28 \times \frac{1}{0.91} \times \frac{1}{0.57} A = 54.6 A$$

From Table (3-6) Column 5 the minimum conductor cross-sectional area that can be used is found to be 10 mm^2 = 69 A.

Example 2
A single-phase circuit is to be wired in 70ºC pvc-insulated and sheathed single-core cables having copper conductors. The cables are to be installed in free air, horizontal, flat spaced on cable supports (Reference Method F). If I_b = 135 A, t_a = 50ºC and overload and short circuit protection is to be provided by a BS 88 ‘gG’ fuse (BS EN60269), what is the minimum current rating for that fuse and the minimum cross-sectional area of the cable conductors that can be used?

Answer

Because $I_n \geq I_b$, select I_n = 160A from the standard ratings of BS 88 Pt 2.
Therefore I_n = 160A.
From Table 4C1, C_a = 0:71,
As there is no grouping, Cg=1

Ci =1 and Cd = 1.

Thus:

$$I_t = 160 \times \frac{1}{0.71}\ A = 225.4\ A$$

From Table (3-11) Column 2 it is found that 50 mm^2 is inadequate because I_{ta} would be only 215 A. The minimum conductor crosssectional area that can be used is 70 mm having I_{ta} = 264 A.

Example 3
Six similar single-phase circuits each having I_b = 8 A are to be wired in single-core 70ºC pvc-insulated non-sheathed cables having copper conductors. The cables are enclosed in conduit totally surrounded by thermally insulating material. If the ambient temperature is expected to be 45ºC and each circuit is protected by a 10 A miniature circuit breaker against both overload and short circuit, what is the minimum cross-sectional area of conductor that can be used?

Answer

From Table (3-18), C_a = 0:79.
From Table (3-13), C_g = 0:57.

From Table (3-4), Reference Method is A1 where the conduit enclosing the cable(s) is totally surrounded by thermally insulating material: in such cases the factor Ci (=0.5) has to be used. Thus:

$$I_t = 10 \times \frac{1}{0.79} \times \frac{1}{0.57} \times \frac{1}{0.5}\ A = 44.4\ A$$

From Column 2 of Table (3-5) it is found that the minimum conductor cross-sectional area that can be used is 10 mm^2 having I_{ta} = 46 A.